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Narrative Bottom Deposits Standard Implementation Procedures

Arizona Department of Environmental Quality
Water Quality Division
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Surface Water Quality Standards & Monitoring Unit

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Executive summary

This document sets forth implementation procedures for the narrative "bottom deposits" water quality standard found at A.A.C. R18-11-108(A)(1). The document explains ADEQ's approach to determining compliance with the narrative bottom deposits standard in an objective way and how ADEQ will use the narrative bottom deposits standard in the §305(b) water quality assessment and §303(d) listing processes.

The existing narrative bottom deposits standard states: "A surface water shall be free from pollutants in amounts or combinations that settle to form bottom deposits that inhibit or prohibit the habitation, growth, or propagation of aquatic life." This narrative standard is intended to prevent excessive sedimentation and siltation in amounts that adversely affect aquatic life. Excessive sediment alters aquatic habitats and suffocates fish eggs and bottom-dwelling organisms. Clean stream bottom substrates are essential for the health of many fish and aquatic insect communities. Habitat degradation due to sedimentation occurs when key habitat components such as spawning gravels and cobble surfaces are covered by fine sediment, decreasing inter-gravel oxygen transfer and reducing or eliminating the quality and quantity of pool and interstitial habitat for fish, benthic macroinvertebrates, and algae.

ADEQ proposes to determine the percentage of fine sediments in riffle / run habitats in perennial streams using a Wolman pebble count procedure to determine compliance with the narrative bottom deposits standard. Fine sediment is defined as particles that are less than 2 mm in size (i.e., sand, clay, and silt). ADEQ proposes to use a minimum percent fines threshold of 20%, below which no impairment of aquatic life occurs. The scientific literature indicates that negative effects to aquatic life are shown to occur at 20-35% fines. Bjornn et. al (1977) found that when the percentage of fine sediment exceeds 20% to 30% in spawning riffles, the survival and emergence of salmonid embryos begins to decline. Similarly, Relyea et al. (2000) found that macroinvertebrate species were lost when the stream substrate composition was between 20-35% percent fines. There is general agreement that fish reproduction is affected and increasing numbers of sensitive macroinvertebrate species are lost at sediment levels greater than 30-35% fines. ADEQ proposes to use a maximum percent fines threshold of 35%, above which both fish and macroinvertebrate communities are definitively known to be impaired. Since there is less certainty about the effects of sediment at levels of 20-35% fines, especially with regard to Arizona streams, ADEQ proposes to conduct a macroinvertebrate bioassessment to corroborate the finding of impairment of the aquatic community. The combination of an impaired bioassessment score and a percent fines value of 20-35% would then result in a finding of aquatic life impairment.

When the percentage of fines in riffle habitats is ≥35%, an exceedance of the narrative bottom deposits standard will result and is grounds for 303(d) listing. If the percentage of fines in riffle habitats is between 20% and 35% AND a bioassessment index score indicates an impaired biological community, ADEQ will find that there is an exceedance of the narrative bottom deposits standard. The latter case also provides grounds for a §303(d) listing.

Acknowledgments

This guidance document was written by Steve Pawlowski and Patti Spindler of the Surface Water Monitoring and Standards Unit, Hydrologic Support & Assessment Section, Water Quality Division, at the Arizona Department of Environmental Quality with contributions from Sam Rector, Diana Marsh and Melanie Diroll, also of ADEQ.

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Introduction:

Excessive sediment alters aquatic habitats, suffocates fish eggs and bottom-dwelling organisms, interferes with drinking water treatment processes, and impairs the recreational uses of rivers and streams. Clean stream bottom substrates are essential for the health of many fish and aquatic insect communities. Habitat degradation due to sedimentation occurs when key habitat components such as spawning gravels and cobble surfaces are covered by fine sediment, decreasing inter-gravel oxygen transfer and reducing or eliminating the quality and quantity of pool and interstitial habitat for fish, benthic macroinvertebrates, and algae.

Excessive sediment of anthropogenic origin is a major stressor of aquatic ecosystems in the United States. According to the EPA National Water Quality Inventory-2000 Report, excessive sediment and siltation were identified as leading causes of water quality impairment of the Nation's rivers and streams (USEPA, 2002). In the 2000 Water Quality Inventory, 31% of all river and stream miles were listed as impaired because of sedimentation.

The protection of aquatic life from excess sedimentation originates from the goals and objectives of the Clean Water Act. Protection of aquatic life is a key component of the Clean Water Act objective "to restore and maintain the chemical, physical and biological integrity of the nation's waters." Protection of aquatic life is reinforced in Clean Water Act Section 101(a)(2) which sets forth the national goal that "…wherever attainable, an interim goal of water quality which provides for protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved." Protection of aquatic life from the adverse effects of excess sedimentation and siltation is provided by the narrative bottom deposits standard.

Arizona's narrative bottom deposits standard is found in the water quality standards rules found in the A.A.C. R18-11-108(A)(1), which states:

> **A surface water shall be free from pollutants in amounts or combinations that… settle to form bottom deposits that inhibit or prohibit the habitation, growth, or propagation of aquatic life.**

It is ADEQ's responsibility to set standards and associated implementation procedures in order to protect human health and aquatic life uses. This document establishes the procedures required to implement and interpret the existing narrative bottom deposits standard to prevent excessive sedimentation and siltation in streams in amounts that adversely affect aquatic life.

Defining Excess Sediment as Regulated by the Narrative Bottom Deposits Standard

The narrative bottom deposits standard is intended to regulate excessive amounts of uncontaminated fine sediment in streams which adversely affect aquatic life. Fine sediment is defined as particles that are less than 2 mm in size (i.e., clay, silt and sand). Fine sediment is also defined as "clean" or uncontaminated sediment for purposes of the bottom deposit standard. Excess sediment means an accumulation of fine particles that settle out of the water column to form deposits on the streambed.

ADEQ uses a modified Wolman pebble count procedure (Wolman, 1954) to calculate the percentage of fine sediment that is present in the stream substrate. In this method, streambed particles are placed into size classes, modified from the Wentworth scale (Table1). These size classes include particles that range from silt and clay (the smallest particle sizes) to sand, gravel, cobbles and boulders (the largest particle size).

Table 1. Particle size classes used in the Wolman pebble count.

Size Class	**Size Range (mm)**
Silt / Clay	<0.062
Sand	0.063 – 2
Very Fine Gravel	3-4
Fine Gravel	5-8
Medium Gravel	9-16
Coarse Gravel	17-32
Very Coarse Gravel	33-64
Small Cobble	65-96
Medium Cobble	97-128
Large Cobble	129-180
Very Large Cobble	181-256
Small Boulder	257-512
Medium Boulder	513-1024
Large Boulder	1025-2048
Very Large Boulder	2049-4096
Bedrock	>4097

Applicability

The narrative bottom deposits standard applies to all "surface waters." "Surface water" is defined in the surface water quality standards rules at A.A.C. R18-11-101(40). The regulatory definition of "surface water" is as follows:

A surface water is a "water of the United States" and includes the following:

a. A water that is currently used, was used in the past, or may be susceptible to use in interstate or foreign commerce;

b. An interstate water, including an interstate wetland;

c. All other waters, such as an intrastate lake, reservoir, natural pond, river, stream (including an intermittent or ephemeral stream), creek, wash, draw, mudflat, sandflat, wetland, slough, backwater, prairie pothole, wet meadow, or playa lake, the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce, including any such water:

    i. That is or could be used by interstate or foreign travelers for recreational or other purposes;

    ii. From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or

    iii. That is used or could be used for industrial purposes by industries in interstate or foreign commerce;

d. An impoundment of a surface water as defined by this definition;

e. A tributary of a surface water identified in subsections (a) through (d) of this definition; and

f. A wetland adjacent to surface water identified in subsections (a) through (e) of this definition.

While the narrative bottom deposits standard technically applies to all surface waters, ADEQ has developed field procedures that can be applied **only in wadeable, perennial stream reaches.** Additional conditions must be met in order to apply the bottom deposits standard; namely the monitoring of particle sizes must be conducted in riffle and run portions of streams. The ADEQ procedure for "Determining Percent Fines" (Appendix A) must be used. The following conditions must be met in order to assess attainment of the bottom deposits standard:

- Wadeable
- Perennial
- Contains riffle or run habitat

Bottom deposits assessments will only be performed for perennial, wadeable stream reaches because the existing research used to develop the procedure was based upon perennial stream data. The narrative bottom deposits standard will not be applied to the following waterbody types because the research and implementation procedures have not yet been developed.

- Lakes, reservoirs, ponds and playas.
- Large rivers (defined as rivers that are too deep to safely wade)
- Intermittent streams
- Ephemeral waters
- Effluent dependent waters
- Wetlands

Adverse Effects of Sediment Deposits on Aquatic Life in Streams

Benthic Macroinvertebrates

There is an extensive body of scientific literature documenting adverse impacts of excessive sedimentation and siltation on aquatic life in streams. In a major review of the effects of sediment in streams, Waters (1995) notes that most of the published research dealing with bottom deposits of sediment and benthic macroinvertebrates addresses three major areas: 1) the correlation between the abundance of benthic macroinvertebrates and substrate particle size, 2) the embeddedness of streambed substrates and habitat loss associated with the decrease in the amount of interstitial space or habitat available to benthic macroinvertebrates, and 3) changes in species composition associated with changes in habitat caused by sedimentation.

In an extensive literature review, Chapman and McLeod (1987) found that benthic macroinvertebrate abundance, diversity and species composition was highly correlated with the quantity of fines in stream courses, as follows:

1) Fine sediment is inversely correlated with abundance of aquatic insects. Aquatic insect abundance was reduced 50% with an increase from 7% to 9% fines (<0.84mm) from a sediment core sample (Cederholm and Lestelle, 1974).

2) Insect abundance and diversity generally declined as a result of sediment addition in an Idaho stream (McClelland and Brusven, 1980). Two stoneflies were highly sensitive to bottom sediment and several species of EPT taxa were moderately sensitive to low amounts of sediment but highly sensitive to large increases in bottom sediment. McClelland found that the microhabitat area beneath cobble was very important for most of the EPT taxa he studied.

3) Loss of species and shifts in species composition occurred in streams with increased percent fines. The highest production of aquatic macroinvertebrates was found in streams with gravel to rubble sized substrate (Reiser and Bjornn, 1979). Five species of aquatic insects studied by Brusven and Prather (1974) generally preferred unembedded cobble substrates to half to completely embedded cobble. Nutall (1972) found that sand deposition

led to increased abundance of a few macroinvertebrates, such as Tubificid worms and two tolerant mayflies, but also led to loss of many other species.

In a study of 652 streams located in four northwestern states, Relyea et al. (2000) found that many macroinvertebrate taxa are lost when fine sediment (<2 mm) in the stream substrate increases to 20-35% percent fines. For example, sensitive macroinvertebrates such as the caddisfly *Neothremma* were lost from streams containing only 20% fines and the mayfly *Drunella doddsi* declined with increasing amounts of sediment and was completely lost at sediment levels of 37% fines. Similar patterns can be expected to occur in Arizona where these taxa or related sensitive taxa are found.

In a study of stream pollution problems associated with sedimentation and urban runoff in North Carolina, Lenat et.al. (1979) found that density, species richness and diversity were decreased with increased sedimentation. They summarized effects of sedimentation upon benthic macroinvertebrate communities, as follows: 1) with small amounts of sediment, the density and standing stock of the benthos may be decreased due to reduction of interstitial habitat, although community structure and species richness may not change, and 2) greater sediment amounts that drastically change the substrate type (i.e. from cobble / gravel to sand / silt) will change the taxonomic composition, thus altering community structure and species diversity. The classic example of taxonomic alteration due to sedimentation is a shift from a community of EPT organisms in the stream to one of oligochaetes (worms) and burrowing chironomids (midges).

Fish

The loss or reduction of fish populations has been associated with sedimentation of streams. Waters (1995) categorized the existing scientific literature on the effects of sediment on fish in streams into 4 main categories: 1) the direct effect of suspended sediment, including turbidity; 2) effects on reproductive success of salmonids; 3) effects on reproductive success on non-salmonid, or warm water fishes; and 4) effects of deposited sediment on the habitat of fry, juvenile, and adult fish.

Most of the published research on the effects of deposited sediment in streams relates to effects on fish, particularly salmonids (e.g., salmon and trout). The adverse effects of deposited sediment on the reproductive success of salmonids have been extensively studied. All North American salmon and trout (including inland trout populations of brook, brown, cutthroat, and other trout) use redds in flowing waters as part of their reproductive strategy. Salmonid redds are vulnerable to deposited sediment because the developing eggs, embryos, and newly hatched sac fry in the redd must be supplied by inter-gravel flows of oxygen-rich water. The primary source of oxygen reaching the redd is in the downwelling water of the stream. The deposition of excessive sediment is a major problem because the sediment deposits interfere with or prevent the transfer of dissolved oxygen within the redd. When excessive sediment settles to form deposit deposits, adverse effects include the coating of fish eggs and embryos and the filling of interstitial spaces in the redd gravel so that the flow of oxygen-rich water through the redd is impeded or stopped. Three adverse effects of excessive sediment on salmonid redds have been recognized: 1) filling of interstitial spaces in the redd by sediment deposits, thus reducing or preventing the flow of water through the redd and the supply of oxygen to the embryos or sac fry; 2) smothering of embryos and sac fry by high concentrations of suspended sediment entering the redd; and 3) entrapment of emerging fry if an armor of consolidated sediment is deposited on the surface of the redd.

In contrast to salmonid reproduction, the effect of sediment upon reproductive success of warm water fishes is less well known. Waters (1995) notes that correlations between warm water fish species distribution and heavy sedimentation in streams suggest some cause and effect relationship, but only circumstantial evidence is available.

The scientific literature on the subject of deposited sediment and fish habitat has concentrated primarily on fish-rearing habitat. Two major areas of study have been investigated: 1) mortality to fish fry by the filling in of the interstitial spaces in riffles of gravel and cobbles, and 2) loss of juvenile-rearing and adult habitat by the filling of pools. Again, most of the research in this area has been done on salmonids. Salmonid fry require the protection of streambed "roughness" conditions for winter survival. Salmonid fry seek the protection of the interstitial spaces in clean stream bed substrates for over-wintering cover. Although not as extensively studied, there is evidence of the adverse effect of deposited sediment on juvenile rearing habitat in pools. When heavy sediment deposits reduce or eliminate pool habitat, reduced growth and loss of fish populations result. Waters (1995) presumed that fry of warm water fishes have similar habitat requirements for survival of early life stages but Waters states that little research has been done on these sediment relationships for warm water fishes.

Bjornn et. al. (1977) found that when the percentage of fine sediment exceeds 20 to 30 percent in spawning riffles, the survival and emergence of salmonid embryos begins to decline. Bjornn et. al. (1977) advocate using the percentage of fine sediment in riffle areas as the primary indicator for monitoring deposition of fine sediment in streams and for determining when too much sediment deposition is occurring.

Determining thresholds for the Narrative Bottom Deposit Standard

ADEQ proposes to use a percentage of fine sediment threshold of 20% for attainment of the aquatic life use. There is general agreement that no impairment of aquatic life occurs below the 20% level, since this was the value at which negative effects begin to occur, cited by both Bjornn and Relyea. Both Bjornn et. al (1977) and Relyea et al. (2000) determined that negative effects to aquatic life began to occur at 20-35% fines. Bjornn et. al (1977) found that when the percentage of fine sediment exceeds 20 to 30 percent in spawning riffles, the survival and emergence of salmonid embryos begins to decline. Similarly, Relyea et al. (2000) found that macroinvertebrate species were lost when the stream substrate composition was between 20-35% percent fines. There is general agreement that fish reproduction is affected and increasing numbers of sensitive macroinvertebrate species are lost at sediment levels greater than 30-35% fines.

ADEQ proposes to use a maximum percent fines threshold of 35%, above which both fish and macroinvertebrate communities are definitively known to be impaired.
Since there is less certainty about the effects of sediment at levels of 20-35% fines, especially with regard to Arizona streams, ADEQ proposes to conduct a macroinvertebrate bioassessment to verify the finding of impairment of the aquatic community. The combination of an impaired bioassessment score and a percent fines value of 20-35% would then result in a finding of aquatic life impairment. Procedures for conducting bioassessments and evaluating the biocriteria standard are described in the Narrative Biocriteria Standard Implementation Procedures document (ADEQ, 2005).

The field procedure to be used for determining percent fines is described in Appendix A. A pebble count will be performed in the riffle or run habitat of wadeable, perennial streams in order to determine the percentage of fines in the stream substrate.

Determining compliance with the Narrative Bottom Deposit Standard

When the percentage of fines in riffle or run habitats in a stream is less than 20%, ADEQ will determine that the stream is meeting the narrative bottom deposits standard and the aquatic life use is supported.

When the percent fines value is between 20–35%, ADEQ will make a determination of inconclusive, whereby a macroinvertebrate bioassessment is required. Procedures for conducting a bioassessment are described in the Narrative Biocriteria Standard Implementation Procedures document (ADEQ, 2005). The bioassessment result, with the percent fines result, will then be used to make a finding of meeting or not meeting the bottom deposit standard. For example, a study reach would be meeting the standard if the percent fines were inconclusive but the bioassessment result was good. A study reach would be considered to be not attaining the standard if the percent fines result was inconclusive and the bioassessment result was impaired.

When the percent fines value is >35%, ADEQ will determine that the stream is exceeding the narrative bottom deposits standard and the aquatic life use is not supported (Table 2).

Table 2. Bottom Deposits thresholds for making aquatic life use determinations.

Percentage of Fine Sediments in Riffles or Runs	Result
< 20 %	Attaining
20 – 35 %	Inconclusive
> 35 %	Impaired

Use of the Narrative Bottom Deposit Standard in §305(b) Water Quality Assessment and §303(d) Listing

Assessment

Assessments of the aquatic life use will be conducted using the same criteria as is used in determining an exceedance of the narrative standard (Table 2). The assessment will be based on a single pebble count result. A single sample is sufficient for assessing whether excess bottom deposits occur because the sample is composited from multiple riffle or run habitats. Also a particle size count which consists of 100 counted particles produces robust and reproducible results, according to a study conducted by Brush (1961).

Listing

There are two ways in which an exceedance of the narrative bottom deposit standard would result in a §303(d) listing of a stream reach:

- When the percentage of fines in riffle or run habitats is >35%, and
- When the percentage of fines in riffle or run habitats is 20% - 35% *and* a bioassessment index score (IBI) indicates an impaired biological community.

In order to delist a waterbody from the 303(d) impaired waters list, the same level of information will be required to delist as to list. When a stream reach is listed as impaired due to a percent fines value that is >35%, a more recent percent fines value that is <20% will be sufficient evidence to delist. When a stream reach is listed as impaired due to a percent fines value that between 20-35% and an impaired IBI score, the IBI score of a new sample must be found to be meeting the Narrative Biocriteria Standard to delist.

Definitions:

Benthic means the bottom of a sea, lake or stream. Benthic macroinvertebrates generally refers to aquatic insects and other invertebrates which reside on stream bottom substrates.

Biological integrity: The capacity of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

Fine sediment refers to the percentage of particles occurring in the stream substrate, which are less than 2 mm in particle size (i.e., clay, silt and sand).

Index of biological integrity means a multimetric tool used for assessing the condition of a biological community.

Interstitial refers to the spaces between grains of sediment in a stream substrate (interstitial spaces).

Macroinvertebrates are invertebrate animals that are large enough to be seen with the naked eye and have no backbone or spinal column; such as insects, snails, and worms.

Perennial surface water means a surface water that flows continuously throughout the year.

Redd - A spawning nest dug in the streambed substrate by a fish, especially a salmon or trout.

Riffle habitat refers to the portions of streams where moderate velocities and substrate roughness produce moderately turbulent conditions which break the surface tension of the water and may produce whitewater.

Run habitat refers to segments of streams where there is moderate velocity water, but non-turbulent conditions which do not break the surface tension of the water and do not produce whitewater.

Substrate refers to the bottom material in a stream, which is composed of a mixture of particle sizes.

Wadeable means no deeper than can be safely waded across when collecting samples. ADEQ recommends sampling in streams that are flowing at velocities and depths whose quotient is less than 9 (eg. Velocity <4.5ft/s x 2 ft deep).

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Appendix A. Field Procedure for Determining Percent Fines

ADEQ will determine the percentage of fine sediment in a stream using a modified Wolman pebble count procedure. This pebble count procedure is used to determine the particle size distribution in a stream reach. The pebble count is conducted in riffle or run habitats located within a 2-meander length study reach. The data collected is used to evaluate whether a bimodal particle size distribution exists and to determine the percentage of fine sediment in the substrate.

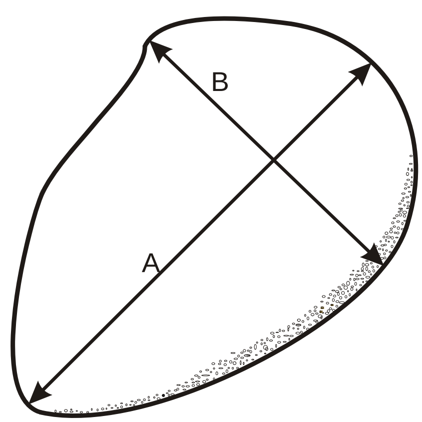
Modified Wolman Pebble Count

1. A study reach of 2 meander length width is first established and marked with flagging tape. Usually three riffles or runs are selected within the study reach for the pebble count. Pebbles are collected for measurement along transects within each habitat, working from the most downstream transect to the most upstream transect.

2. A tape is set up with bank pins across each transect. If three habitats are worked, divide the stream width by thirty three to obtain the increment needed to collect 33 particles across the transect in a single pass. Do not collect particles closer than 0.3 tenths of a foot apart. If 33 particles cannot be collected in one pass along the transect, make a second or third pass as close as possible to the transect tape, and working in an upstream direction without collecting pebbles from the same area worked in the first pass.

3. Particles are selected for measurement. To minimize bias in selecting particles, each over the toe of the wader with the forefinger **without looking down**, pick up the first pebble touched, and measure the intermediate axis (neither the longest nor shortest of the three mutually perpendicular sides) in millimeters.

   A = Longest Axis (length)
   B = Intermediate Axis (width)
   Thickness = Shortest Axis



   The particle size range is determined and the tally is recorded on the Field Data Sheet. Embedded rocks are measured in place by measuring the smaller of the two exposed axes.

   Caution - there is a tendency to look down and select a pebble, but this should be avoided or the results will be biased toward larger particle sizes.

4. The particle is discarded behind and downstream, before moving to the next station on the transect, and sampling another pebble.

5. The transect is worked from wetted edge to wetted edge of the streambed. After completing the first 33 measurements at the first transect, move upstream to the next transect and repeat the process. One hundred counts is the ideal number for this procedure. The whole transect should be completed, rather than stopping data collection in mid-transect when 100 count is reached. Sample counts are allowed to vary ±10 counts (90-110 particles).
6. Sum the counts before leaving the stream, to ensure that the goal of 100±10 pebbles have been counted. If the count is within a count of ten, it is an acceptable pebble count.